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WQR-1.2
ADDENDUM 1
Rev. 0
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PART TITLE: WVDP WASTE FORM QUALIFICATION REPORT -
WASTE FORM SPECIFICATIONS

ITEM TITLE: RADIONUCLIDE INVENTORY SPECIFICATION

1.2 Radionuclide Inventory Specification

Addendum 1 - Radionuclide Scaling Factors

Per the commitment in Waste Form Qualification Report Section 1.2, "Radionuclide Inventory Specification," this addendum provides the background for, and final determination of, the scaling factors to be used in the reporting of the radionuclide inventory in the High-Level Waste (HLW) glass waste form.

The Pacific Northwest National Laboratory (PNNL) analyzed a sample of waste from the initial transfer of material from Tank 8D-2 to the Concentrator Feed Make-Up Tank (CFMT) on June 24, 1996. Table 10 of the PNNL report¹ provides the radioanalytical results. The results are summarized in Table 1.

The Waste Acceptance Product Specification (WAPS)² 1.2 Radionuclide Inventory Specification states the following:

The producer shall report the inventory of radionuclide (in Curies) that have half-lives longer than 10 years and that are, or will be, present in concentrations greater than 0.05 percent of the total radioactive inventory for each waste type, indexed to the years 2015 and 3115.

The WAPS requirements are met by reporting the estimated radionuclide content of the canistered waste forms based on glass shard sample analyses³, satisfying the requirements of WAPS 1.1 and 1.3. The radionuclide information for Sr-90 and Cs-137 were directly measured from these shards by beta and gamma energy analysis, respectively. For those 28 canisters sampled, the results for Sr-90 and Cs-137 will be reported directly from the shard measurements. The values for these isotopes for the remaining canisters will be the geometric mean of the values of those analyzed. These data are reported in data package WVNS-DP-035⁴.

The remaining reportable radionuclide inventory will be estimated using scaling factors (i.e. ratios developed for each reportable isotope to Sr-90 or Cs-137). The Sr-90 and Cs-137 values measured from the shard samples would then be multiplied by the scaling factors to obtain the estimated inventories for the other reportable species. Two cesium isotopes (Cs-134 and Cs-135) are scaled to Cs-137. All others are scaled to Sr-90.

Two adjustments/additions have been made to the data reported in the PNNL report. The metastable isotope of americium-242 (Am-242m) could not be measured. It can, however, be calculated from the amount of curium-242 (Cm-242), as that is the sole source of that curium isotope. When Am-242m decays⁵, it first goes to Am-242 (99.55%) then to Cm-242 (82.7%). Using this information, the amount of Am-242m can then be calculated from the amount of Cm-242 measured by multiplying by 1.215.

The analysis done by PNNL reports the curium isotopes as Cm-243+244. It is necessary to separate these two radioisotopes to report them properly to meet WAPS 1.2. Table 22 of Rykken⁶ reports the presence of 31 curies of Cm-243 and 20,000 curies of Cm-244 as of July 1, 1987. Using the equation below⁷, these values can be decayed to the analysis date of June 11, 1997, and the ratio of the two isotopes calculated for that date.

$$[X]_a = [X]_b \exp((\ln 2) (\Delta t) / t_{1/2})$$

where,

[X]_a = radionuclide amount or concentration, in Curies or Curies/gram, at time a
[X]_b = radionuclide amount or concentration, in Curies or Curies/gram, at time b
Δt = difference in time, in years, between a and b
t_{1/2} = radionuclide half-life, in years.

The results of this equation show that for the wastes found at the WVDP as of June 11, 1997 the relative amounts of these two isotopes are 99.82% Cm-244 and 0.18% Cm-243. Those are the factors used to separate the data provided by PNNL for Cm-243+244.

Table 1 also reports the adjustment of the data to the required reporting date of January 1, 1996. The analyses are adjusted using the above equation.

To calculate the radionuclide concentration for the other required reporting dates of January 1, 2015, and January 1, 3115, a standard program called Microshield^{TM,8} was used. MicroshieldTM uses the decay scheme equation above for calculating the decay of the radionuclides. The program also provides the radionuclides which "grow in" as a result of the decay. The "in-growth" radionuclides for the years 2015 and 3115 are also listed in Table 1. These data then provide the basis for determining which radionuclides are reportable for WAPS 1.2 and for calculating the scaling factors. The starting point for the MicroshieldTM analysis was the concentration for each radionuclide determined at the time of analysis reported by PNNL, which is contained in the third and fourth columns in Table 1.

To conform to the WAPS 1.2, WVNSCO has committed to report all those radionuclides with half lives greater than 10 years that are present (at each reportable year) in quantities greater than 0.01% of the total amount of radionuclides contained in the glass. All radionuclides are used when determining the percentage present, regardless of half-life. The order of the screening, then, is first based on the amount present, followed by elimination for short half-life. The survivors of this screening are listed in Table 2.

Table 3 reports the scaling factors for all of the radionuclides as determined from the analysis presented in Table 1.

The scaling factors reported in WQR 1.2 for the years 1996, 2015, and 3115 are listed in Table 4. Table 5 is a compilation of the scaling factors determined by comparing those generated by this analysis and those reported in the original WQR 1.2. The most conservative value has been selected; that is, the value which would result in having the highest amount of radionuclide present was chosen to be used for these analyses.

The Production Records related to WQR 1.2 are required to contain the amounts of the reportable radionuclides for the years 1996, 2015, and 3115. The radioisotopes are identified in Table 2. The scaling factors listed in Table 5 will be used to determine the values to be recorded in the Production Records. (See Reference 9.)

Data package WVNS-DP-035⁴ and calculation WVNS-CAL-325¹⁰ contain the information and calculations required to report the radionuclide inventories and uranium and plutonium contents of the glass canistered waste form.

UNCERTAINTY

Appendix A to Reference 1 provides the raw data for the radionuclide analyses done on WVDP waste by PNNL. Table 6 lists the percent error given in that report for each radionuclide. Where no percent error values are provided in Reference 1, a value of 100% will be used for the uncertainty.

Also, Cm-243 and Cm-244 were analyzed together so the percent error was assumed to be the same for both. Additionally, the value for Am-242m was calculated from the value for Cm-242, so they would have the same percent error.

Following previous work in estimating scaling factors¹¹, the estimated error for the individual radionuclide scaling factors are a combination of the analytical errors of the individual radionuclide and the scaling radionuclide (either Sr-90 or Cs-137). They are combined as follows:

$$\text{error}_{\text{sf}} = (\text{error}_i^2 + \text{error}_{\text{sr}}^2)^{1/2}$$

Where:

error_{sf} = total error for the scaling factor
 error_i = analytical error for individual radionuclides, and
 error_{sr} = analytical error for the scaling radionuclide.

REFERENCES

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6. Rykken, L. E. (1986). "High-Level Waste Characterization at West Valley, Progress Report for the Period 1982-1985," Topical Report DOE/NE/44139-14, June 2.
7. West Valley Nuclear Services Co (1994). WVNS-CAL-109, Reference Insoluble Waste and Decay Calculations for WQR Section 1.2, West Valley Demonstration Project, West Valley, NY.
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10. West Valley Nuclear Services Co. (2003). WVNS-CAL-325, Radionuclide Inventory for HLW Glass Production Records, West Valley Demonstration Project, West Valley, NY.
11. West Valley Nuclear Services Co. (1994). WVNS-CAL-108, Radioactive Scaling Factor and Error Estimate, West Valley Demonstration Project, West Valley, NY.

Table 1. Data Summary From PNNL Report WVSP 00-28

Radionuclide	Half-Life (years)	Measured Concentration (uCi/g)	Analysis Date	Adjusted to January 1, 1996 (uCi/g)	Adjusted to January 1, 1996 (percentage)	Adjusted to January 1, 2015 (uCi/g)	Adjusted to January 1, 2015 (percentage)	Adjusted to January 1, 3115 (uCi/g)	Adjusted to January 1, 3115 (percentage)
Cs-137	3.02E+01	2.85E+03	June 11, 1997	2.94E+03	49.624	1.90E+03	25.753	2.01E-08	0.000
Sr-90	2.86E+01	2.75E+03	July 2, 1997	2.86E+03	48.140	1.80E+03	24.392	4.76E-09	0.000
C-14	5.73E+03	4.90E-04	June 16, 1997	4.90E-04	0.000	4.89E-04	0.000	4.28E-04	0.005
Ni-59	7.50E+04	7.00E-02	July 8, 1997	7.00E-02	0.001	7.00E-02	0.001	6.93E-02	0.793
Co-60	5.27E+00	8.84E-01	June 11, 1997	1.07E+00	0.018	8.79E-02	0.001	1.32E-04	0.000
Ni-63	1.00E+02	7.36E+00	July 8, 1997	7.44E+00	0.125	6.52E+00	0.088	3.21E-03	0.037
Se-79	6.50E+04	2.00E-05	December 18, 1997	2.00E-05	0.000	2.00E-05	0.000	1.98E-05	0.000
Nb-93m	1.46E+01	5.80E-02	July 16, 1997	6.24E-02	0.001	9.19E-02	0.001	1.20E-01	1.372
Zr-93	1.53E+06	1.20E-01	December 19, 1997	1.20E-01	0.002	1.20E-01	0.002	1.20E-01	1.372
Tc-99	2.13E+05	8.45E-02	November 10, 1998	8.45E-02	0.001	8.45E-02	0.001	8.42E-02	0.963
Pd-107	6.50E+06	3.00E-04	June 26, 1997	3.00E-04	0.000	3.00E-04	0.000	3.00E-04	0.003
Sn-126	1.06E+05	3.00E-03	July 2, 1997	3.00E-03	0.000	3.00E-03	0.000	2.98E-03	0.034
Cs-134	2.06E+00	2.40E-01	October 27, 1997	4.43E-01	0.007	7.45E-04	0.000	1.92E-164	0.000
Cs-135	2.30E+06	3.22E-02	June 30, 1997	3.22E-02	0.001	3.22E-02	0.000	3.22E-02	0.368
Sm-151	9.00E+01	1.17E+01	July 16, 1997	1.18E+01	0.200	1.02E+01	0.138	2.14E-03	0.024
Eu-154	8.80E+00	2.34E+01	June 11, 1997	2.62E+01	0.442	5.87E+00	0.079	1.38E-37	0.000
Ac-227	2.18E+01	1.20E-02	January 22, 1998	1.28E-02	0.000	8.24E-02	0.001	2.83E-02	0.324
Pa-231	3.28E+04	2.90E-02	June 26, 1997	2.90E-02	0.000	2.90E-02	0.000	2.83E-02	0.324
Th-232	1.41E+10	1.50E-03	June 26, 1997	1.50E-03	0.000	1.50E-03	0.000	1.50E-03	0.017
U-233	1.59E+05	3.60E-03	June 26, 1997	3.60E-03	0.000	3.60E-03	0.000	3.70E-03	0.042
U-234	2.45E+05	1.30E-03	June 26, 1997	1.30E-03	0.000	1.48E-03	0.000	2.86E-03	0.033
U-235	7.04E+08	3.80E-05	June 26, 1997	3.80E-05	0.000	3.80E-05	0.000	3.92E-05	0.000
U-236	2.34E+07	1.10E-04	June 26, 1997	1.10E-04	0.000	1.10E-04	0.000	1.35E-04	0.002
U-238	4.47E+09	3.40E-04	June 26, 1997	3.40E-04	0.000	3.40E-04	0.000	3.40E-04	0.004
Np-236	1.15E+05	3.00E-05	July 17, 1997	3.00E-05	0.000	3.00E-05	0.000	2.98E-05	0.000
Np-237	2.14E+06	2.00E-02	June 26, 1997	2.00E-02	0.000	2.02E-02	0.000	2.56E-02	0.293
Pu-236	2.85E+00	2.20E-02	July 2, 1997	3.17E-02	0.001	3.15E-04	0.000	2.65E-06	0.000
Pu-238	8.78E+01	3.96E+00	July 2, 1997	4.01E+00	0.068	3.48E+00	0.047	3.84E-03	0.044
Pu-239	2.41E+04	1.09E+00	July 2, 1997	1.09E+00	0.018	1.09E+00	0.015	1.07E+00	12.205
Pu-240	6.57E+03	7.70E-01	July 2, 1997	7.70E-01	0.013	7.78E-01	0.011	7.01E-01	8.019
Pu-241	1.44E+01	3.43E+01	July 2, 1997	3.69E+01	0.622	1.48E+01	0.200	1.49E-22	0.000
Pu-242	3.76E+05	8.50E-04	July 2, 1997	8.50E-04	0.000	8.51E-04	0.000	8.67E-04	0.010
Am-241	4.32E+02	3.21E+01	June 11, 1997	3.22E+01	0.543	3.18E+01	0.431	5.54E+00	63.435
Am-242m	1.52E+02	2.79E-01	June 11, 1997	2.80E-01	0.005	2.57E-01	0.003	1.70E-03	0.019
Am-243	7.38E+03	3.60E-01	October 27, 1997	3.60E-01	0.006	3.59E-01	0.005	3.24E-01	3.709
Cm-242	4.46E-01	2.30E-01	June 11, 1997	2.17E+00	0.037	2.12E-01	0.003	1.40E-03	0.016
Cm243	2.85E+01	1.24E-02	June 11, 1997	1.29E-02	0.000	1.68E-01	0.002	4.04E-13	0.000
Cm244	1.81E+01	6.97E+00	June 11, 1997	7.36E+00	0.124	3.43E+00	0.046	1.78E-18	0.000
Total		5.72E+03	Total	5.93E+03	100.000				

From Rykken, Table 22

Nuclide	Fractional Activity
Cm-243	0.0018
Cm-244	0.9982

"Measured" value for Am-242m is calculated from Cm-242.

Half-lives are taken from Microshield.

Data for 2015 and 3115 are taken from Microshield decay programs based on the Measured Concentration data.

Table 1. Data Summary From PNNL Report WVSP 00-28 (continued)

Radionuclide (In-Growth)	Half-Life (years)	Measured Concentration (uCi/g)	Analysis Date	Adjusted to January 1, 1996 (uCi/g)	Adjusted to January 1, 1996 (percentage)	Adjusted to January 1, 2015 (uCi/g)	Adjusted to January 1, 2015 (percentage)	Adjusted to January 1, 3115 (uCi/g)	Adjusted to January 1, 3115 (percentage)
Ac-225	2.74E-02	N/A	N/A	N/A	N/A	5.92E-06	0.000	3.65E-04	0.004
Ac-228	7.00E-04	N/A	N/A	N/A	N/A	1.32E-03	0.000	1.50E-03	0.017
At-217	1.83E-03	N/A	N/A	N/A	N/A	5.92E-06	0.000	3.65E-04	0.004
Am-242	1.02E-09	N/A	N/A	N/A	N/A	2.55E-01	0.003	1.69E-03	0.019
Ba-137m	4.85E-06	N/A	N/A	N/A	N/A	1.80E+03	24.362	1.90E-08	0.000
Bi-210	1.37E-02	N/A	N/A	N/A	N/A	1.28E-10	0.000	4.96E-06	0.000
Bi-211	4.05E-06	N/A	N/A	N/A	N/A	8.26E-02	0.001	2.83E-02	0.324
Bi-212	1.15E-04	N/A	N/A	N/A	N/A	1.98E-03	0.000	1.53E-03	0.017
Bi-213	8.69E-05	N/A	N/A	N/A	N/A	5.92E-06	0.000	3.65E-04	0.004
Bi-214	3.79E-05	N/A	N/A	N/A	N/A	8.12E-10	0.000	5.25E-06	0.000
Fr-221	9.13E-06	N/A	N/A	N/A	N/A	5.92E-06	0.000	3.65E-04	0.004
Fr-223	4.15E-05	N/A	N/A	N/A	N/A	1.14E-03	0.000	3.91E-04	0.004
Np-238	5.80E-03	N/A	N/A	N/A	N/A	1.22E-03	0.000	8.10E-06	0.000
Np-239	6.45E-03	N/A	N/A	N/A	N/A	3.59E-01	0.005	3.24E-01	3.709
Pa-233	7.40E-02	N/A	N/A	N/A	N/A	2.02E-02	0.000	2.56E-02	0.293
Pa-234	7.65E-04	N/A	N/A	N/A	N/A	5.44E-07	0.000	5.44E-07	0.000
Pa-234m	2.23E-06	N/A	N/A	N/A	N/A	3.40E-04	0.000	3.40E-04	0.004
Pb-209	3.71E-04	N/A	N/A	N/A	N/A	5.92E-06	0.000	3.65E-04	0.004
Pb-210	2.23E+01	N/A	N/A	N/A	N/A	1.28E-10	0.000	4.96E-06	0.000
Pb-211	6.87E-05	N/A	N/A	N/A	N/A	8.26E-02	0.001	2.83E-02	0.324
Pb-212	1.21E-03	N/A	N/A	N/A	N/A	1.98E-03	0.000	1.53E-03	0.017
Pb-214	5.10E-05	N/A	N/A	N/A	N/A	8.12E-10	0.000	5.25E-06	0.000
Po-210	3.79E-01	N/A	N/A	N/A	N/A	1.17E-10	0.000	4.95E-06	0.000
Po-211	1.64E-08	N/A	N/A	N/A	N/A	2.25E-04	0.000	7.74E-05	0.001
Po-212	9.45E-15	N/A	N/A	N/A	N/A	1.27E-03	0.000	9.63E-04	0.011
Po-213	1.33E-13	N/A	N/A	N/A	N/A	5.79E-06	0.000	3.57E-04	0.004
Po-214	5.20E-12	N/A	N/A	N/A	N/A	8.12E-10	0.000	5.25E-06	0.000
Po-215	5.64E-11	N/A	N/A	N/A	N/A	8.26E-02	0.001	2.83E-02	0.324
Po-216	4.63E-09	N/A	N/A	N/A	N/A	1.98E-03	0.000	1.53E-03	0.017
Po-218	5.80E-06	N/A	N/A	N/A	N/A	8.13E-10	0.000	5.25E-06	0.000
Ra-223	3.13E-02	N/A	N/A	N/A	N/A	8.26E-02	0.001	2.83E-02	0.324
Ra-224	9.92E-03	N/A	N/A	N/A	N/A	1.98E-03	0.000	1.53E-03	0.017
Ra-225	4.05E-02	N/A	N/A	N/A	N/A	5.93E-06	0.000	3.65E-04	0.004
Ra-226	1.60E+03	N/A	N/A	N/A	N/A	8.13E-10	0.000	5.25E-06	0.000
Ra-228	5.75E+00	N/A	N/A	N/A	N/A	1.32E-03	0.000	1.50E-03	0.017
Rn-219	1.26E-07	N/A	N/A	N/A	N/A	8.26E-02	0.001	2.83E-02	0.324
Rn-220	1.76E-06	N/A	N/A	N/A	N/A	1.98E-03	0.000	1.53E-03	0.017
Rn-222	1.05E-02	N/A	N/A	N/A	N/A	8.12E-10	0.000	5.25E-06	0.000
Sb-126	3.40E-02	N/A	N/A	N/A	N/A	4.20E-04	0.000	4.17E-04	0.005
Sb-126m	3.61E-05	N/A	N/A	N/A	N/A	3.00E-03	0.000	2.98E-03	0.034
Th-227	5.13E-02	N/A	N/A	N/A	N/A	8.14E-02	0.001	2.80E-02	0.320
Th-228	1.91E+00	N/A	N/A	N/A	N/A	1.98E-03	0.000	1.53E-03	0.017
Th-229	7.34E+03	N/A	N/A	N/A	N/A	5.95E-06	0.000	3.65E-04	0.004
Th-230	7.70E+04	N/A	N/A	N/A	N/A	2.20E-07	0.000	2.66E-05	0.000
Th-231	2.91E-03	N/A	N/A	N/A	N/A	3.80E-05	0.000	3.98E-05	0.000
Th-234	5.86E-02	N/A	N/A	N/A	N/A	3.40E-04	0.000	3.40E-04	0.004
Tl-207	9.08E-06	N/A	N/A	N/A	N/A	8.24E-02	0.001	2.83E-02	0.323
Tl-208	5.81E-06	N/A	N/A	N/A	N/A	7.12E-04	0.000	5.40E-04	0.006
Tl-209	4.19E-06	N/A	N/A	N/A	N/A	1.28E-07	0.000	7.89E-06	0.000
U-232	7.20E+01	N/A	N/A	N/A	N/A	7.54E-04	0.000	2.67E-06	0.000
U-237	1.28E-05	N/A	N/A	N/A	N/A	3.62E-04	0.000	3.66E-27	0.000
Y-90	7.01E-03	N/A	N/A	N/A	N/A	1.80E+03	24.398	4.76E-09	0.000
TOTALS				5.93E+03	1.00E+02	7.39E+03	100.000	8.74E+00	100.000

Table 2. Reportable Radionuclides for WQR 1.2

	1996	2015	3115
Cs-137	YES	YES	NO
Sr-90	YES	YES	NO
C-14	NO	NO	NO
Ni-59	NO	NO	YES
Co-60	NO	NO	NO
Ni-63	YES	YES	YES
Se-79	NO	NO	NO
Nb-93m	NO	NO	YES
Zr-93	NO	NO	YES
Tc-99	NO	NO	YES
Pd-107	NO	NO	NO
Sn-126	NO	NO	YES
Cs-134	NO	NO	NO
Cs-135	NO	NO	YES
Sm-151	YES	YES	YES
Eu-154	NO	NO	NO
Ac-227	NO	NO	YES
Pa-231	NO	NO	YES
Th-232	NO	NO	YES
U-233	NO	NO	YES
U-234	NO	NO	YES
U-235	NO	NO	NO
U-236	NO	NO	NO
U-238	NO	NO	NO
Np-236	NO	NO	NO
Np-237	NO	NO	YES
Pu-236	NO	NO	NO
Pu-238	YES	YES	YES
Pu-239	YES	YES	YES
Pu-240	YES	YES	YES
Pu-241	YES	YES	NO
Pu-242	NO	NO	NO
Am-241	YES	YES	YES
Am-242m	NO	NO	YES
Am-243	NO	NO	YES
Cm-242	YES	NO	YES
Cm-243	NO	NO	NO
Cm-244	YES	YES	NO

**Table 3. Radionuclide Ratios for WQR 1.2, 1.6, and 3.14
(from Table 1)**

	1996	2015	3115
Cs-137	1.00E+00	1.00E+00	1.00E+00
Sr-90	1.00E+00	1.00E+00	1.00E+00
C-14	1.72E-07	2.71E-07	8.99E+04
Ni-59	2.45E-05	3.88E-05	1.46E+07
Co-60	3.74E-04	4.88E-05	2.78E-56
Ni-63	2.61E-03	3.62E-03	6.74E+05
Se-79	7.01E-09	1.11E-08	4.15E+03
Nb-93m	2.19E-05	5.10E-05	2.52E+07
Zr-93	4.20E-05	6.66E-05	2.52E+07
Tc-99	2.96E-05	4.69E-05	1.77E+07
Pd-107	1.05E-07	1.67E-07	6.30E+04
Sn-126	1.05E-06	1.67E-06	6.25E+05
Cs-134	1.50E-04	3.92E-07	9.56E-157
Cs-135	1.09E-05	1.69E-05	1.60E+06
Sm-151	4.15E-03	5.68E-03	4.50E+05
Eu-154	9.18E-03	3.26E-03	2.90E-29
Ac-227	4.49E-06	4.57E-05	5.95E+06
Pa-231	1.02E-05	1.61E-05	5.95E+06
Th-232	5.25E-07	8.33E-07	3.15E+05
U-233	1.26E-06	2.00E-06	7.78E+05
U-234	4.55E-07	8.23E-07	6.00E+05
U-235	1.33E-08	2.11E-08	8.23E+03
U-236	3.85E-08	6.13E-08	2.83E+04
U-238	1.19E-07	1.89E-07	7.14E+04
Np-236	1.05E-08	1.67E-08	6.26E+03
Np-237	7.01E-06	1.12E-05	5.38E+06
Pu-236	1.11E-05	1.75E-07	5.57E+02
Pu-238	1.40E-03	1.93E-03	8.08E+05
Pu-239	3.82E-04	6.05E-04	2.24E+08
Pu-240	2.70E-04	4.32E-04	1.47E+08
Pu-241	1.29E-02	8.20E-03	3.14E-14
Pu-242	2.98E-07	4.73E-07	1.82E+05
Am-241	1.13E-02	1.77E-02	1.16E+09
Am-242m	9.81E-05	1.42E-04	3.57E+05
Am-243	1.26E-04	2.00E-04	6.81E+07
Cm-242	7.60E-04	1.18E-04	2.95E+05
Cm-243	4.50E-06	9.33E-05	8.50E-05
Cm-244	2.58E-03	1.91E-03	3.75E-10

**Cs-134 and Cs-135 are scaled to Cs-137
All others are scaled to Sr-90.**

**Table 4. Radionuclide Scaling Factors for WQR 1.2, 1.6, and 3.14
(from WQR 1.2 Table 6)**

	1996	2015	3115
Cs-137	1.00E+00	1.00E+00	1.00E+00
Sr-90	1.00E+00	1.00E+00	1.00E+00
C-14	2.36E-05	3.69E-05	7.74E+06
Ni-59	1.82E-05	2.87E-05	6.80E+06
Co-60	N/A	N/A	N/A
Ni-63	1.41E-03	1.92E-03	1.15E+05
Se-79	1.04E-05	1.63E-05	3.85E+06
Nb-93m	3.56E-05	6.69E-05	1.76E+07
Zr-93	4.68E-05	7.36E-05	1.76E+07
Tc-99	2.93E-04	4.60E-04	1.10E+08
Pd-107	1.89E-06	2.98E-06	7.13E+05
Sn-126	1.79E-05	2.81E-05	6.68E+06
Cs-134	N/A	N/A	N/A
Cs-135	2.56E-05	3.97E-05	4.33E+06
Sm-151	1.39E-02	1.88E-02	9.43E+05
Eu-154	N/A	N/A	N/A
Ac-227	1.62E-06	3.26E-06	9.62E+05
Pa-231	2.62E-06	4.11E-06	9.62E+05
Th-232	2.82E-07	4.44E-07	1.06E+05
U-233	1.64E-06	2.58E-06	6.22E+05
U-234	7.94E-07	1.36E-06	4.93E+05
U-235	N/A	N/A	N/A
U-236	N/A	N/A	N/A
U-238	N/A	N/A	N/A
Np-236	1.63E-06	2.56E-06	6.09E+05
Np-237	4.04E-06	6.44E-06	2.13E+06
Pu-236	N/A	N/A	N/A
Pu-238	1.38E-03	1.88E-03	2.93E+05
Pu-239	2.84E-04	4.46E-04	1.04E+08
Pu-240	2.09E-04	3.31E-04	7.09E+07
Pu-241	1.06E-02	6.65E-03	5.22E+04
Pu-242	2.84E-07	4.47E-07	1.08E+05
Am-241	9.21E-03	1.44E-02	5.99E+08
Am-242m	4.97E-05	7.17E-05	1.14E+05
Am-243	5.97E-05	9.36E-05	2.02E+07
Cm-242	N/A	N/A	N/A
Cm-243	N/A	N/A	N/A
Cm-244	1.04E-03	7.94E-04	9.64E-11

**Cs-134 and Cs-135 are scaled to Cs-137
All others are scaled to Sr-90.**

**Table 5. Final Radionuclide Scaling Factors for WQR 1.2, 1.6, and 3.14
(Taking the most conservative values from Tables 4 and 5)**

	1996	2015	3115
Cs-137	1.00E+00	1.00E+00	1.00E+00
Sr-90	1.00E+00	1.00E+00	1.00E+00
C-14	2.36E-05	3.69E-05	7.74E+06
Ni-59	2.45E-05	3.88E-05	1.46E+07
Co-60	3.74E-04	4.88E-05	2.78E-56
Ni-63	2.61E-03	3.62E-03	6.74E+05
Se-79	1.04E-05	1.63E-05	3.85E+06
Nb-93m	3.56E-05	6.69E-05	2.52E+07
Zr-93	4.68E-05	7.36E-05	2.52E+07
Tc-99	2.93E-04	4.60E-04	1.10E+08
Pd-107	1.89E-06	2.98E-06	7.13E+05
Sn-126	1.79E-05	2.81E-05	6.68E+06
Cs-134	1.50E-04	3.92E-07	9.56E-157
Cs-135	2.56E-05	3.97E-05	4.33E+06
Sm-151	1.39E-02	1.88E-02	9.43E+05
Eu-154	9.18E-03	3.26E-03	2.90E-29
Ac-227	4.49E-06	4.57E-05	5.95E+06
Pa-231	1.02E-05	1.61E-05	5.95E+06
Th-232	5.25E-07	8.33E-07	3.15E+05
U-233	1.64E-06	2.58E-06	7.78E+05
U-234	7.94E-07	1.36E-06	6.00E+05
U-235	1.33E-08	2.11E-08	8.23E+03
U-236	3.85E-08	6.13E-08	2.83E+04
U-238	1.19E-07	1.89E-07	7.14E+04
Np-236	1.63E-06	2.56E-06	6.09E+05
Np-237	7.01E-06	1.12E-05	5.38E+06
Pu-236	1.11E-05	1.75E-07	5.57E+02
Pu-238	1.40E-03	1.93E-03	8.08E+05
Pu-239	3.82E-04	6.05E-04	2.24E+08
Pu-240	2.70E-04	4.32E-04	1.47E+08
Pu-241	1.29E-02	8.20E-03	5.22E+04
Pu-242	2.98E-07	4.73E-07	1.82E+05
Am-241	1.13E-02	1.77E-02	1.16E+09
Am-242m	9.81E-05	1.42E-04	3.57E+05
Cm-242	7.60E-04	1.18E-04	2.95E+05
Cm-243	4.50E-06	9.33E-05	8.50E-05
Cm-244	2.58E-06	1.91E-03	3.75E-10

**Cs-134 and Cs-135 are scaled to Cs-137.
All others are scaled to Sr-90.**

**Table 6. Analytical Uncertainties and Estimated Errors
in the Scaling Factors**

Radionuclide	Percent Error (analytical)	Percent Error (scaling factor)
Cs-137	2	2
Sr-90	3	3
C-14	100	100
Ni-59	11	11
Co-60	6	7
Ni-63	11	11
Se-79	100	100
Nb-93m	22	22
Zr-93	9	9
Tc-99	100	100
Pd-107	100	100
Sn-126	24	24
Cs-134	9	9
Cs-135	100	100
Sm-151	15	15
Eu-154	2	4
Ac-227	7	8
Pa-231	100	100
Th-232	100	100
U-233	6	7
U-234	6	7
U-235	6	7
U-236	6	7
U-238	6	7
Np-236	38	38
Np-237	100	100
Pu-236	38	38
Pu-238	5	6
Pu-239	6	7
Pu-240	6	7
Pu-241	100	100
Pu-242	100	100
Am-241	4	5
Am-242m	16	16
Am-243	9	9
Cm-242	16	16
Cm243	5	6
Cm244	5	6

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ADDENDUM 1
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WVNSCO RECORD OF REVISION

Rev. No.	Description of Changes	Revision On Page(s)	Dated
0	Original Issue High Level Waste Process and WQR Compliance Engineering	All	05/01/03